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APPLICATION NUMBER: ***60/529,443***
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RELATED PCT APPLICATION NUMBER: ***PCT/US04/25989***

Certified by

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17621 U.S.PTO
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. ER 870951132 US

INVENTOR(S)

Given Name (first and middle [if any]	Family Name or Surname	Residence (City and either State or Foreign Country)
Craig	Siders	Orlando, FL

Additional inventors are being named on the ____________ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Optical Pulse Stretching and Compressing

Direct all correspondence to: CORRESPONDENCE ADDRESS

☐ Customer Number:

OR

☒ Firm or Individual Name	Ablation Industries, Inc.				
Address	12565 Research Pkwy, Ste. 300				
Address					
City	Orlando	State	FL	Zip	32826
Country	USA	Telephone	407 882-0208	Fax	407 737-2512

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 9

☒ Drawing(s) *Number of Sheets* 12

☐ Application Date Sheet. See 37 CFR 1.76

☐ CD(s), Number ____________

☐ Other (specify) ____________

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☒ Applicant claims small entity status. See 37 CFR 1.27.

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

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Respectfully submitted,

SIGNATURE Anastasia Canavan

TYPED or PRINTED NAME Anastasia Canavan

TELEPHONE 407-383-4816

Date 12/12/03

REGISTRATION NO. ____________
(if appropriate)
Docket Number: ABI-29

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

17621 U.S. PTO
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FEE TRANSMITTAL for FY 2004

Effective 10/01/2003. Patent fees are subject to annual revision.

[X] Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT ($) 80.00

Complete if Known	
Application Number	
Filing Date	12/12/03
First Named Inventor	Craig Siders
Examiner Name	
Art Unit	
Attorney Docket No.	ABI-29

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fee	
1004	770	2004	385	Reissue filing fee	
1005	160	2005	80	Provisional filing fee	

SUBTOTAL (1) ($) 80.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims	12	-20** =		X		=	
Independent Claims	1	- 3** =		X		=	
Multiple Dependent						=	

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** Reissue independent claims over original patent
1205	18	2205	9	** Reissue claims in excess of 20 and over original patent

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FEE CALCULATION (continued)

3. ADDITIONAL FEES

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1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet	
1053	130	1053	130	Non-English specification	
1812	2,520	1812	2,520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1,840*	1805	1,840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1,480	2254	740	Extension for reply within fourth month	
1255	2,010	2255	1,005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1,510	1451	1,510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive - unavoidable	
1453	1,330	2453	665	Petition to revive - unintentional	
1501	1,330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Petitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR 1.129(b))	
1801	770	2801	385	Request for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) ______

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SUBTOTAL (3) ($) Ø

SUBMITTED BY				(Complete *(if applicable)*)	
Name *(Print/Type)*	Anastasia Canavan	Registration No. (Attorney/Agent)		Telephone	407-383-4816
Signature	Anastasia Canavan			Date	12/12/03

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Optical Pulse Stretching and Compressing

Abstract

Ablative material removal with a series of high-power, ultra-short (e.g. sub-picosecond) optical pulses is especially useful for a number of purposes (including medical) as the ablation is essentially non-thermal and applies essential no pressure to the surface. In order to amplify the pulse at a reasonable power level, ablative pulses have been created by generating low-power, ultra-short pulses, which are then stretched, amplified, and compressed back to an ultra-short durations. Described herein is a novel way of performing the stretching and/or compressing that provides for higher efficiency, greater temporal stretching/compressing, and more accurate reduction to the original pulse duration in a package that is smaller, lighter, and less expensive.

Background

Ablative material removal is useful for a number of purposes, as it is essentially non-thermal and exerts essentially no pressure on the surface. Ablative removal of material is generally done with a short optical pulse that is stretched, amplified and then compressed. A number of types of laser amplifiers have been used for the amplification.

Laser ablation is very efficiently done with a beam of very short pulses (generally a pulse-duration of three picoseconds or less). While some laser machining melts portions of the work-piece, this type of material removal is ablative, disassociating the surface atoms. Techniques for generating these ultra-short pulses are described, e.g., in a book entitled "Femtosecond Laser Pulses" (C. Rulliere – editor), published 1998, Springer-Verlag Berlin Heidelberg New York. Generally large systems, such as Ti:Sapphire, are used for generating ultra-short pulses (USP).

USP phenomenon was first observed in the 1970's, when it was discovered that mode-locking a broad-spectrum laser could produce ultra-short pulses. The minimum pulse duration attainable is limited by the bandwidth of the gain medium, which is inversely proportional to this minimal or Fourier-transform-limited pulse duration. Mode-locked pulses are typically very short and will spread (*i.e.*, undergo temporal dispersion) as they traverse any medium. Subsequent pulse-compression techniques are often used to obtain USP's. A diffraction grating compressor is shown, e.g. in Patent 5,822,097 by Tournois. Pulse dispersion can occur within the laser cavity so that compression techniques are sometimes added intra-cavity. When high-power pulses are desired, they are intentionally lengthened (e.g. to a nanosecond) before amplification to avoid internal component optical damage. This is referred to as "Chirped Pulse Amplification" (CPA). The pulse is subsequently compressed to obtain a high peak power (*pulse-energy amplification* and *pulse-duration compression*).

Summary

In order to handle the very high powers involved while avoiding amplifier overheating, ablative pulses have been created by generating an ultra-short (e.g. sub-picosecond) pulse, stretching and amplifying the pulses, and then compressing the pulses back to an ultra-short duration. This is an improved way of performing the stretching and/or compressing that provides for higher efficiency, greater temporal stretching/compressing, and more accurate reduction to the original pulse duration in a package that is smaller, lighter, and less expensive.

This diffracting grating stretching/compressing method uses inputting a tilted collimated beam, spatial-spreading the beam, spatial-narrowing the beam, spatial-spreading the beam, spatial-narrowing the beam, and collimating the beam output, wherein the beam hits at least one of the gratings more than once (because of the tilt, the beam hits such a grating at a different line or point each time around). In systems with larger tilts, e.g. more than ¾ degree, collimating of an intermediate spatially-narrowed beam, then manipulating the beam to correct spatial-chirp with, e.g. a retro-reflector mirror-pair or prism. The gratings may be transmissive or reflective. A sub-picosecond original pulse can have a range of wavelengths (spectral width), and thus the pulse length can be stretched by the device. A wavelength-swept-with-time (and amplified) pulse can be compressed by such a device.

The tilted beam makes it possible to go around more than once and still extract the stretched or compressed output beam. By spatial-spreading and spatial-narrowing the beam a number of times, the path length difference can be made large without making the maximum spatial width large, thus minimizing one dimension of the device. By having the beam have a helical path or a path reflecting back and forth (e.g. between two reflective gratings), minimizes another dimension.

In one embodiment, four transmission chirped gratings are used to diffract the beam in a generally helical path, such that the beam hits at least one of the gratings more than once (because of the tilt, the beam hits such a grating at a different point each time around). With a positive chirp, the longer wavelengths are diffracted less and thus take a longer path around the central axis of the gratings and are delayed more than the shorter wavelengths.

In another embodiment, two reflective gratings are used in Littrow angle configuration. In yet another embodiment, one reflective grating and one mirror are used in Littrow angle configuration.

This can be a chirped-diffraction-grating implemented method of temporally stretching or compressing optical pulses containing various wavelengths, comprising; inputting a tilted collimated beam; spatial-spreading the beam; spatial-narrowing the beam; spatial-spreading the beam; spatial-narrowing the beam; and collimating the beam output, wherein path length and delay vary by wavelength and the pulses are temporally modified, and wherein the tilt causes the beam to hit at least one of the gratings more than once at a different line or point on the more-than-once-hit grating.

In some embodiments, after the inputting the tilted collimated beam, spatial-spreading the beam, and spatial-narrowing the beam, the beam is collimated and a retro-reflector mirror-pair or prism is used to correct spatial-chirp (and the beam is reintroduced for further spatial-spreading and spatial-narrowing of the beam).

In a first embodiment, four transmission diffracting grating portions having a first chirp are positioned around a central axis, and the beam is diffracted by the gratings alternately spatial-spreading and spatial-narrowing the beam, to travel around the central axis in a non-planar path.

In a second embodiment, two reflection-grating portions having a second chirp are positioned to alternately spatial-spread the beam and spatial-narrowing the beam.

In a third embodiment, one reflection-grating portion having a third chirp and a mirror are positioned to alternately spatial-spread the beam and spatial-narrowing the beam.

In the above first, second and third embodiments, an input grating portion and an output grating portion may be used, the input grating spatial-spreading the tilted collimated input beam and the output grating collimating a beam being spatially narrowed, the input grating portion and an output grating portion having a chirp different from the first, second or third chirp. Preferably, the input grating and output grating portions are combined with one of diffracting grating portions having a first, second or third chirp. The second and third chirps can be the same and the input/output chirp on the second and third embodiments can be the same.

Such stretching and/or compression of pulses can be used in a laser ablation system.

Brief Description of the Drawings

Other characteristics of the invention may be better understood by used of the following drawings, in which:

Figure 1 is an isometric of transmissive gratings that stretch or compress and shows a beam traveling in a generally helical path;

Figure 2 shows a graph of grooves/mm vs. distance from the center axis and other design data for a helical path device;

Figure 3 shows gratings for a helical path device;

Figure 4 show an isometric of two reflective chirped grating in Littrow Angle configuration
with beam path, and a retro-reflector for spatial-chirp correction;

Figure 5 shows gratings for the two reflective chirped grating device;

Figure 6 shows groove density in grooves/mm vs. position on the grating for the two reflective chirped grating device;

Figure 7 shows an isometric of a compact reflective device and beam path using one reflective chirped grating and one mirror and a retro-reflector for spatial-chirp correction;

Figure 8 is an isometric (approximately to scale) comparing the size of a traditional stretcher/compressor with the compact design of Figure 7;

Figure 9 shows gratings and groove density in grooves/mm vs. position on the grating for the one reflective chirped grating device of Figure 7;

Figure 10 shows groove density in grooves/mm vs. position on the grating for two reflective chirped grating device or one reflective chirped grating and one mirror device operating with a 1550 nm beam (as opposed to the designs above for a 800 nm beam); and

Figure 11 shows groove density in grooves/mm vs. position on the grating for two reflective chirped grating device or one reflective chirped grating and one mirror device operating with a 980 nm beam (as opposed to the designs above for a 800 nm beam).

Description of the Preferred Embodiments

In order to handle the very high powers involved while avoiding amplifier overheating, ablative pulses have been created by generating an ultra-short (e.g. sub-picosecond) pulse, stretching and amplifying the pulses, and then compressing the pulses back to an ultra-short duration. This is an improved way of performing the stretching and/or compressing that provides for higher efficiency, greater temporal stretching/compressing, and more accurate reduction to the original pulse duration in a package that is smaller, lighter, and less expensive.

This diffracting grating stretching/compressing method uses inputting a tilted collimated beam, spatial-spreading the beam, spatial-narrowing the beam, spatial-spreading the beam, spatial-narrowing the beam, and collimating the beam output, wherein the beam hits at least one of the gratings more than once (because of the tilt, the beam hits such a grating at a different line or point each time around).

In one embodiment, four transmission chirped gratings are used to diffract the beam in a generally helical path, such that the beam hits at least one of the gratings more than once (because of the tilt, the beam hits such a grating at a different point each time around). Figure 1 shows such an embodiment. The collimated beam of pulses that are to be temporally modified (either stretched or compressed) comes from the left and enters the first grating (almost perpendicularly; it has a slight upwards tilt). The first grating diffracts the beam at an angle toward the second grating (maintaining the slight upwards tilt), which second grating is at a right angle to the first grating. The first grating also spatially spreads the beam (the beam becomes wider in an essentially horizontal plane) as

it travels from the first to the second grating. The design specifications are shown in Figure 2, including the groove density as a function of position on the grating (in groves per mm, or gpmm). The gratings are shown (not to scale and only a few grooves are shown; but the varying spacing of the grooves is indicated) on Figure 3. While 3 gratings are the same, the 4-th grating has an input and output portions (e.g. the input portion on the bottom and the output portion on the top) that have twice the groove spacings of the middle portion. The middle portion of the 4-th grating has the same spacings as the other 3 gratings. As can be seen, only portions of the gratings are used, and the gratings need not extend in to meet at the center axis. For 99 % diffraction efficiency, total efficiency of the device is 91 %. This example has two complete turns and with a 20 nm pulse spectral width gives about 40 ps of stretching/compressing. With about twice the size and 25 turns, this type of device can give about 1 ns of stretching/compressing, with reasonable efficiency.

A device having similar transmissive gratings disposed at right angles is shown in Figure 4 of U.S. Patent 5,822,097 by Tournois, which also give different pathlengths to different wavelength. Tournois, however, uses an input/spatial-spreading grating spatial-narrowing grating and a collimating output grating and thus he uses a single spatial-spread and spatial-narrowing of the beam. He also has an incoming beam perpendicular to the input grating and all rays of light stay in a single plane.

In the embodiment of Figure 4, two reflective gratings are used in a right angle configuration. The gratings separation is about 5 inches. The gratings of this embodiment are shown in Figure 5. The groove density as a function of position on the grating is shown in Figure 6. Grating height (along the grooves) depends on the tilt angle and for a 1 degree tilt, grating height is about 25 mm (1 inch). Grating width depends on the gratings separation and here is less than 5 mm. A retro-reflector (prism or a mirror pair) is used to compensate for a spatial chirp of the output beam, resulting from the tilt. For the 1 degree tilt, the apex angle has to be equal to 90 degrees 40 minutes. The performance of this embodiment is similar to that of the helical path embodiment. Note that here the beam centerline is in one plane and the rays are fanned out into multiple different planes that are perpendicular to the beam centerline plane.

In the embodiment of Figure 7, one reflective grating and one mirror are used in a 45-degree angle configuration. The device length is reduced by a factor of 2 (down to 2.5 inches). Fabrication cost and time are reduced, as there is just one grating to make. The alignment is significantly simpler, as there one just needs to make sure the grating and the mirror are at 45 degrees and the mirror is perpendicular to rays. The mirror dimensions are 25 mm x 5 mm. The grating height (along the grooves) again depends on the tilt angle, here, with the 1 degree tilt, the grating height is 25 mm (1 inch), and the grating width depends on the separation between the grating and the mirror and is less than 5 mm. A retro-reflector (prism or a mirror pair) is again used to compensate for a spatial chirp of the output beam, resulting from the tilt (for 1 degree tilt the apex angle is equal to 90 degrees 40 minutes). Figure 8 shows size comparison between this compact design and a traditional stretcher. Figure 9 shows a grating and groove density as a function of position on the grating for this embodiment.

As compared to the two reflective grating device, the one reflective grating and one mirror does have a decrease in efficiency due to losses at the mirror. Note that here the beam centerline is also in one plane and the rays are also fanned out into multiple different planes that are perpendicular to the beam centerline plane.

The groove densities as a function of position on the grating for the embodiment Figure 1-9 are for 800 nm devices. Figure 10 shows groove density as a function of position on the grating for 1550 nm embodiments (input/output grating graph shown above and other grating graph shown below). Figure 11 shows groove density as a function of position on the grating for 980 nm embodiments (input/output grating graph shown above and other grating graph shown below).

Preferably, 1550 nm light is used both for safety purposes, and for greater pulse compression efficiency. Preferably we ablate with pulse energy densities at about three times the ablation threshold for greater ablation efficiency.

This technique can be used for either stretching or compressing, but is preferably used for compressing. Another alternative is generating a wavelength-swept-with-time initial pulse for the optically-pumped pulse amplifier input and compressing (thus compressing without using a stretcher). At 1550 nm compression is much more efficient than at shorted wavelengths. With longer distances between elements and/or more diffractions, longer stretches and/or compressions can be used, for example operation with a 10 nanosecond stretch/compression or more may be possible.

Note that electrically-pumped semiconductor optical amplifiers or optically-pumped optical pulse amplifiers in general (including, and in such shapes as slabs, discs, and rods) can be used as in co-pending provisional applications. In some embodiments, the mirror is an active mirror, and diode pump-current may be used to control the amplification of the active mirror.

These stretchers and/or compressors can be used in systems in generally the same manner as such devices in the four co-pending and co-owned applications noted below by docket number, title and provisional number, were filed May 20, 2003 and are hereby incorporated by reference herein: Docket number ABI-1 Laser Machining – provisional application # 60/471,922; ABI-4 "Camera Containing Medical Tool" # 60/472,071; ABI-6 "Scanned Small Spot Ablation With A High-Rep-Rate" # 60/471,972; ABI-7 "Stretched Optical Pulse Amplification and Compression", # 60/471,971. These amplifiers can be controlled and/or used in systems in generally the same manner as the fiber amplifier of the eleven co-pending applications noted below by docket number, title and provisional number, were filed August 11, 2003 and are hereby incorporated by reference herein: ABI-8 "Controlling Repetition Rate Of Fiber Amplifier" -#60/494102; ABI-9 "Controlling Pulse Energy Of A Fiber Amplifier By Controlling Pump Diode Current" – #60/494275; ABI-10 "Pulse Energy Adjustment For Changes In Ablation Spot Size" – #60/494274; ABI-11 "Ablative Material Removal With A Preset Removal Rate or Volume or Depth" – #60/494273; ABI-12 " Fiber Amplifier With A Time Between

Pulses Of A Fraction Of The Storage Lifetime"; ABI-13 "Man-Portable Optical Ablation System" – #60/494321; ABI-14 "Controlling Temperature Of A Fiber Amplifier By Controlling Pump Diode Current" – #60/494322; ABI-15 "Altering The Emission Of An Ablation Beam for Safety or Control" – #60/494267; ABI-16 "Enabling Or Blocking The Emission Of An Ablation Beam Based On Color Of Target Area" – #60/494172; ABI-17 "Remotely-Controlled Ablation of Surfaces" – #60/494276 and ABI-18 "Ablation Of A Custom Shaped Area" – #60/494180. These amplifiers can be controlled and/or used in systems in generally the same manner as the fiber amplifier of the two co-pending applications noted below by docket number and, title that were filed on 9/12/03: co-owned ABI-20 "Spiral-Laser On-A-Disc" inventor- Richard Stoltz; and partially co-owned ABI-21 "Laser Beam Propagation in Air" inventors- Jeff Bullington and Craig Siders.

Although the present invention and its advantages have been described above, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular embodiments of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification, but only by the claims.

Claims:

1. A chirped-diffraction-grating implemented method of temporally stretching or compressing optical pulses containing various wavelengths, comprising;

inputting a tilted collimated beam;

spatial-spreading said beam;

spatial-narrowing the beam;

spatial-spreading said beam;

spatial-narrowing said beam; and

collimating the beam output, wherein path length and delay vary by wavelength and the pulses are temporally modified, and wherein the tilt causes the beam to hit at least one of the gratings more than once at a different line or point on the more-than-once-hit grating.

2. The grating method of claim 1, wherein after said inputting the tilted collimated beam, spatial-spreading the beam, and spatial-narrowing the beam, said beam is collimated and a retro-reflector mirror-pair or prism is used to correct spatial-chirp.

3. The grating method of claim 1, wherein four transmission diffracting grating portions having a first chirp are positioned around a central axis, and the beam is diffracted by the gratings alternately spatial-spreading and spatial-narrowing the beam, to travel around said central axis in a non-planar path.

4. The method of claim 3, wherein an input grating portion and an output grating portion are used, said input grating spatial-spreading the tilted collimated input beam and said output grating collimating a beam being spatially narrowed, said input grating portion and an output grating portion having a chirp different from said first chirp.

5. The method of claim 4, wherein said input grating and output grating portion are combined with one of diffracting grating portions having a first chirp.

6. The method of claim 1, wherein two reflection grating portions having a second chirp are positioned to alternately spatial-spread said beam and spatial-narrowing the beam.

7. The method of claim 6, wherein an input grating portion and an output grating portion are used, said input grating spatial-spreading the tilted collimated input beam and said output grating collimating a beam being spatially narrowed, said input grating portion and an output grating portion having a chirp different from said second chirp.

8. The method of claim 7, wherein said input grating and output grating portion are combined with one of diffracting grating portions having a second chirp.

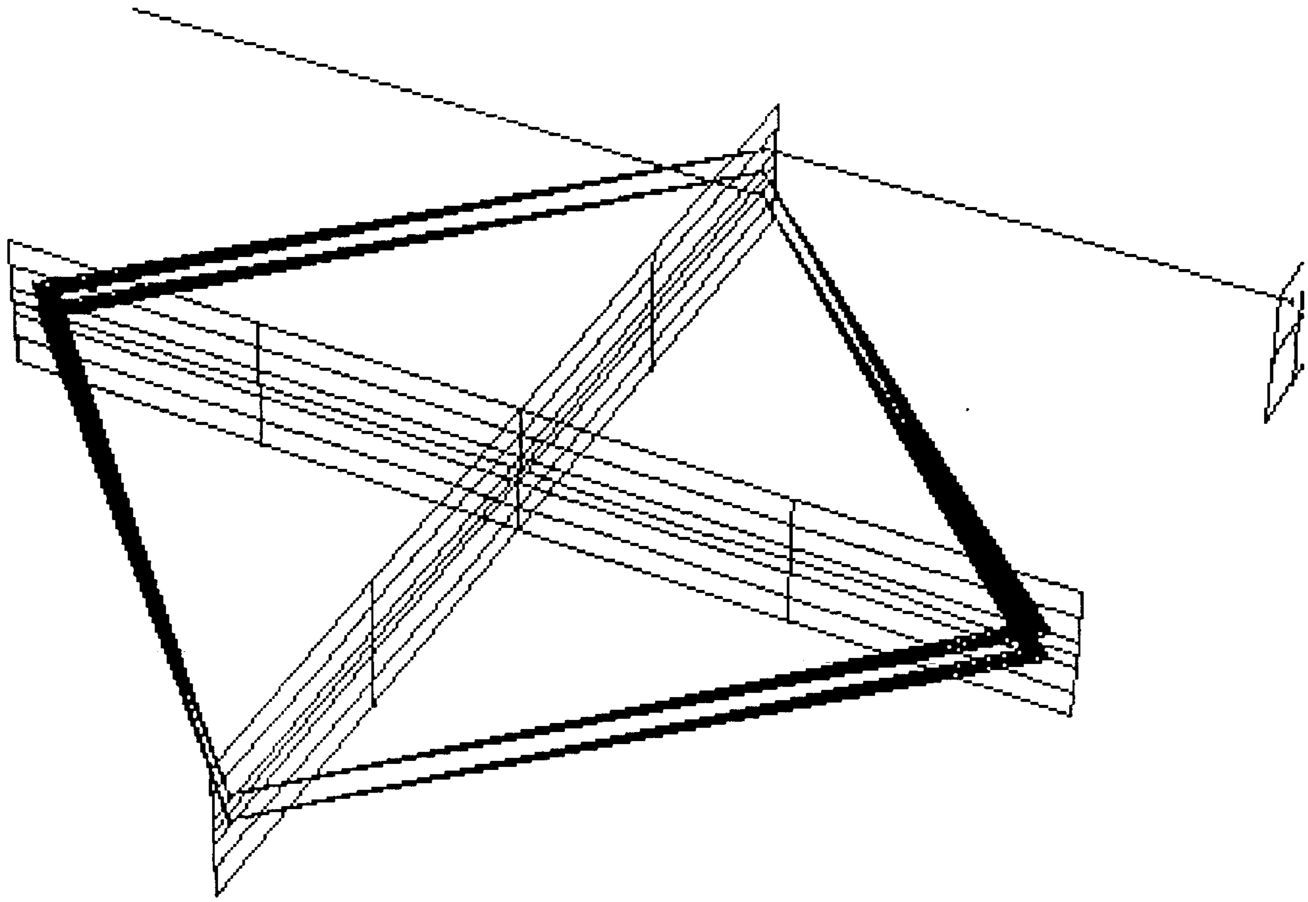
9. The method of claim 1, wherein one reflection grating portion having a third chirp and a mirror are positioned to alternately spatial-spread said beam and spatial-narrowing the beam.

10. The method of claim 9, wherein an input grating portion and an output grating portion are used, said input grating spatial-spreading the tilted collimated input beam and said output grating collimating a beam being spatially narrowed, said input grating portion and an output grating portion having a chirp different from said third chirp.

11. The method of claim 10, wherein said input grating and output grating portion are combined with one of diffracting grating portions having a second chirp.

12. The method of claim 1, wherein pulses are used in a laser ablation system.

Figure 1



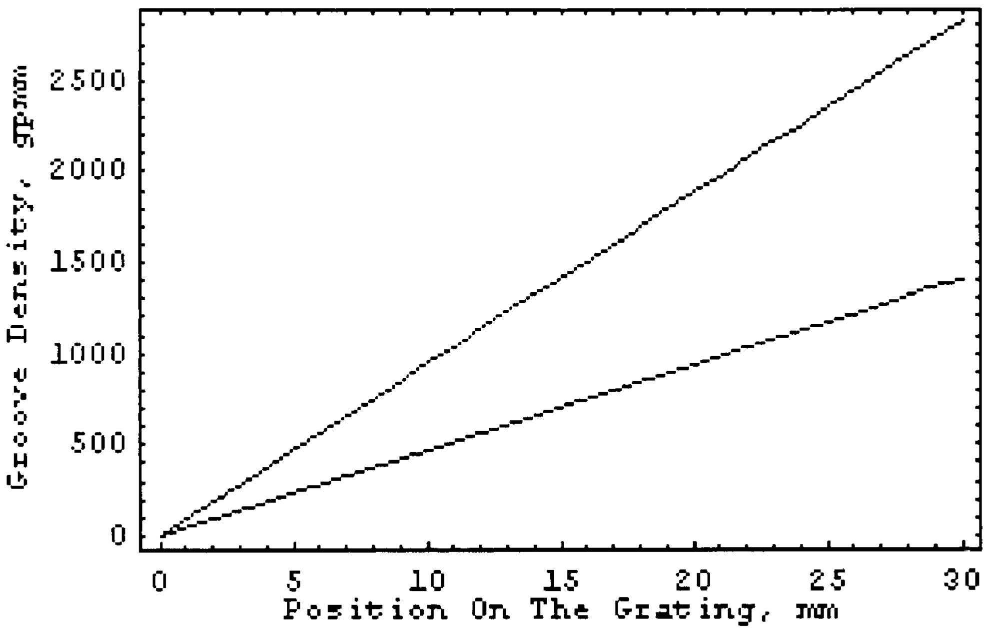


Figure 2

Total Distance travelled by the beam ~ 212.823 mm

Skew Angle of the beam = 0.520291°

Approximate System Dimensions: 4 x 4 x 0.483143 cm

Center Wavelength = 0.8 microns

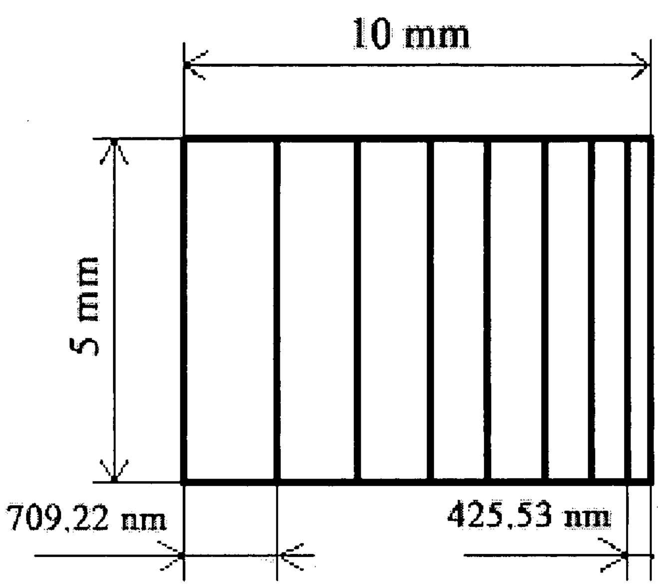
$\Delta\lambda$ = 20. nm

2 Round Trips in the Helicon

Expected GDD = 301580. fs^2

Figure 3

3 gratings



4-th grating

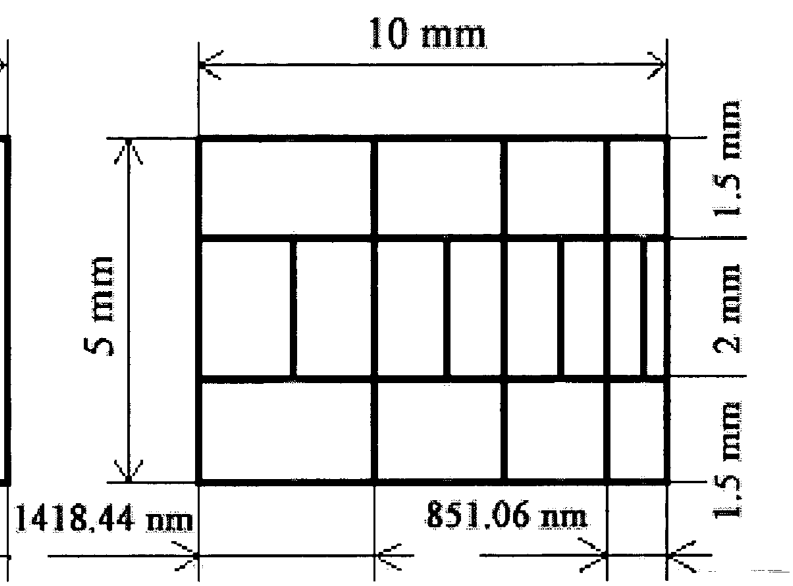


Figure 4

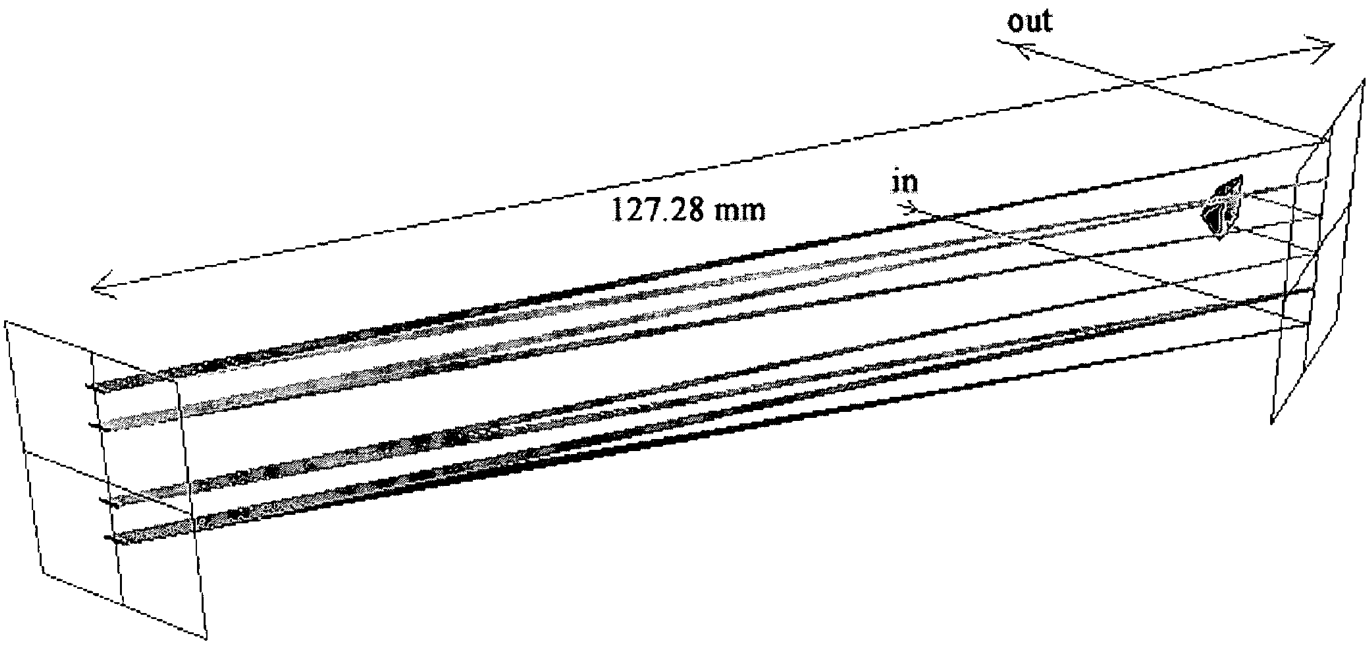
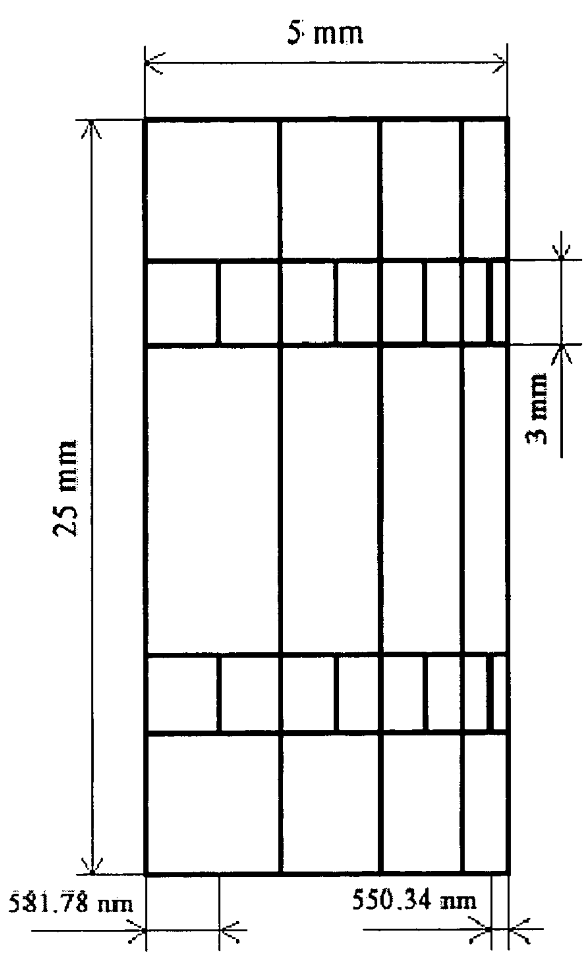


Figure 5

Input/output grating



Other grating

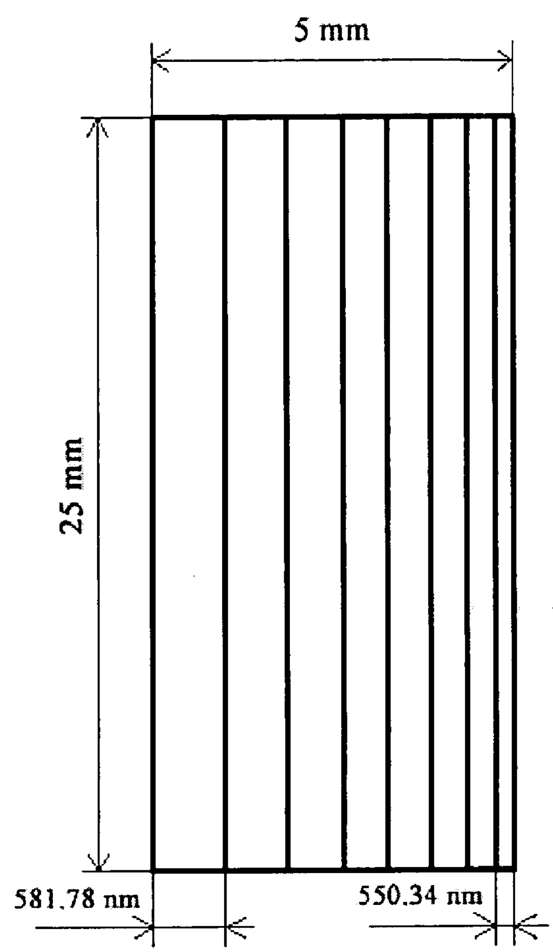
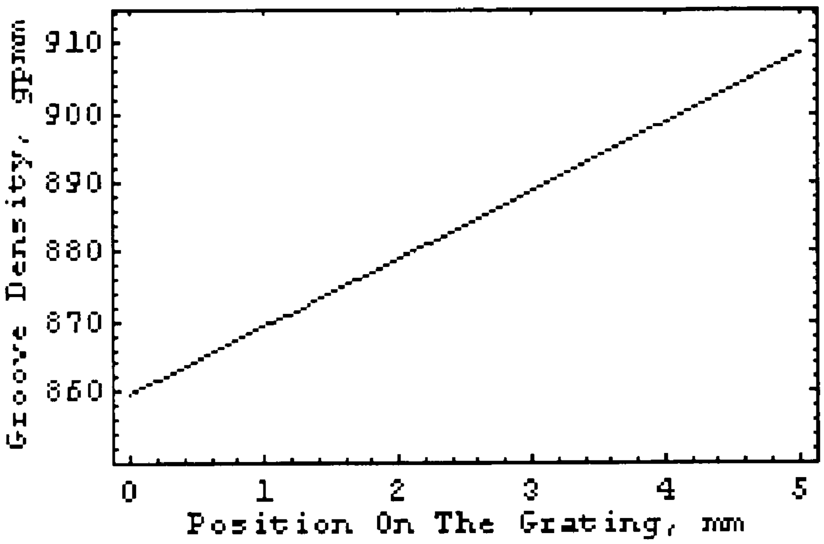


Figure 6

Input/output portion



other portions

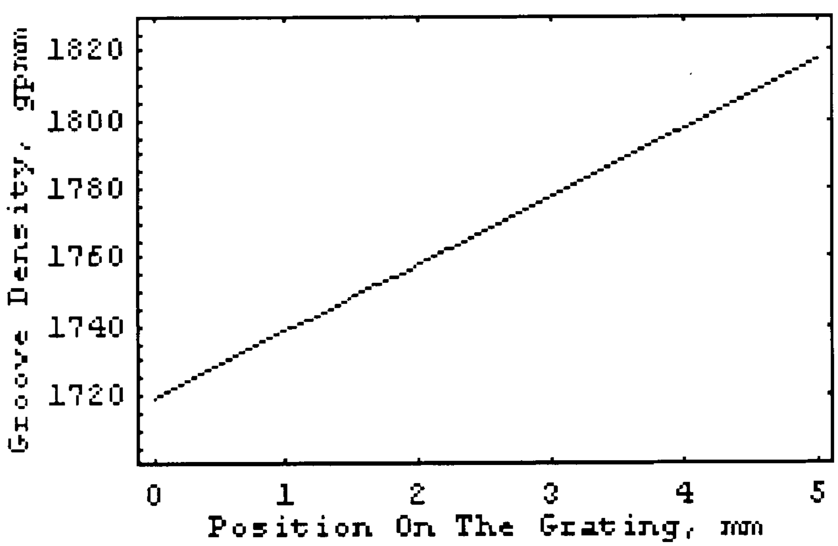


Figure 7

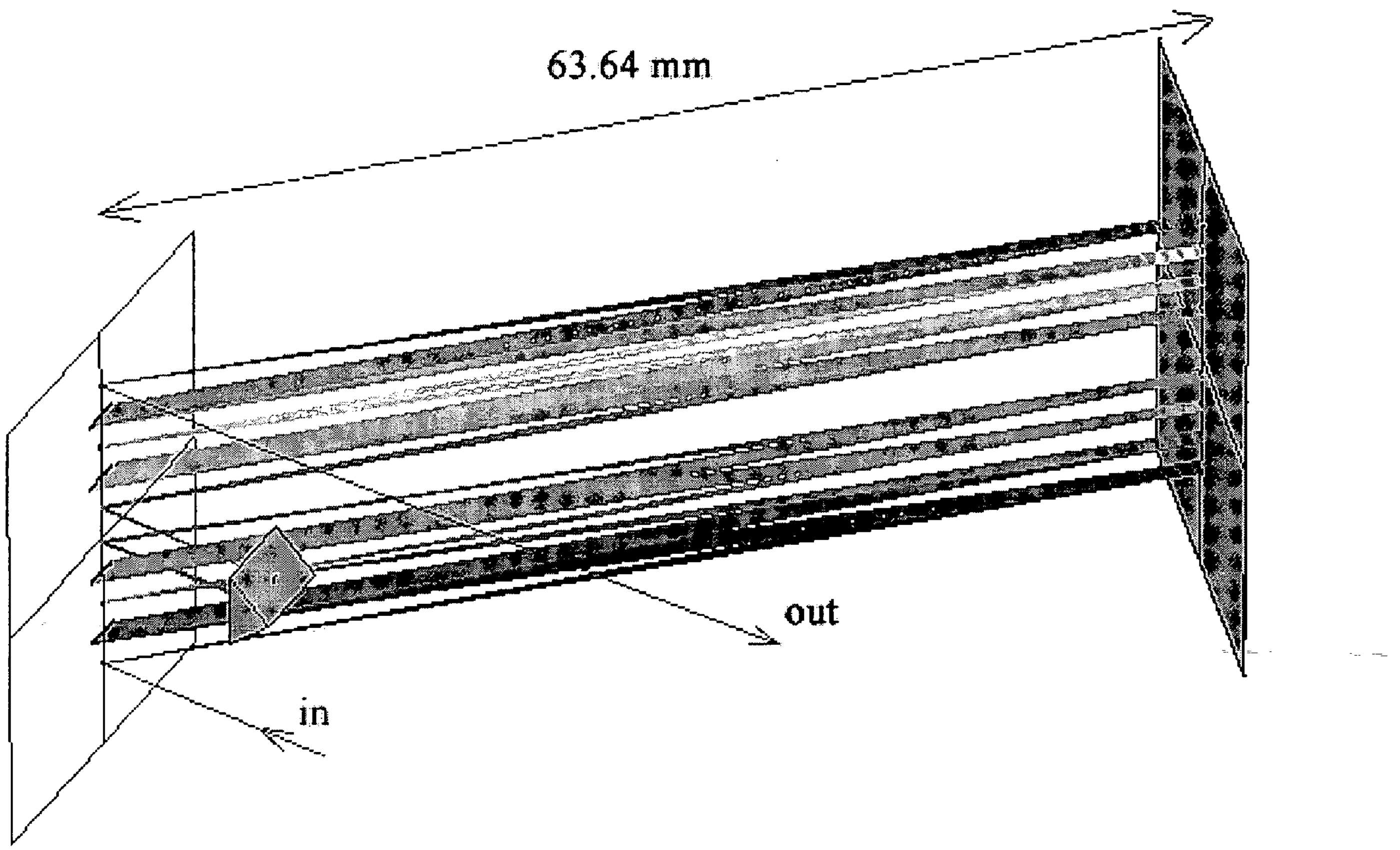


Figure 8

6.3 cm vs 100 cm

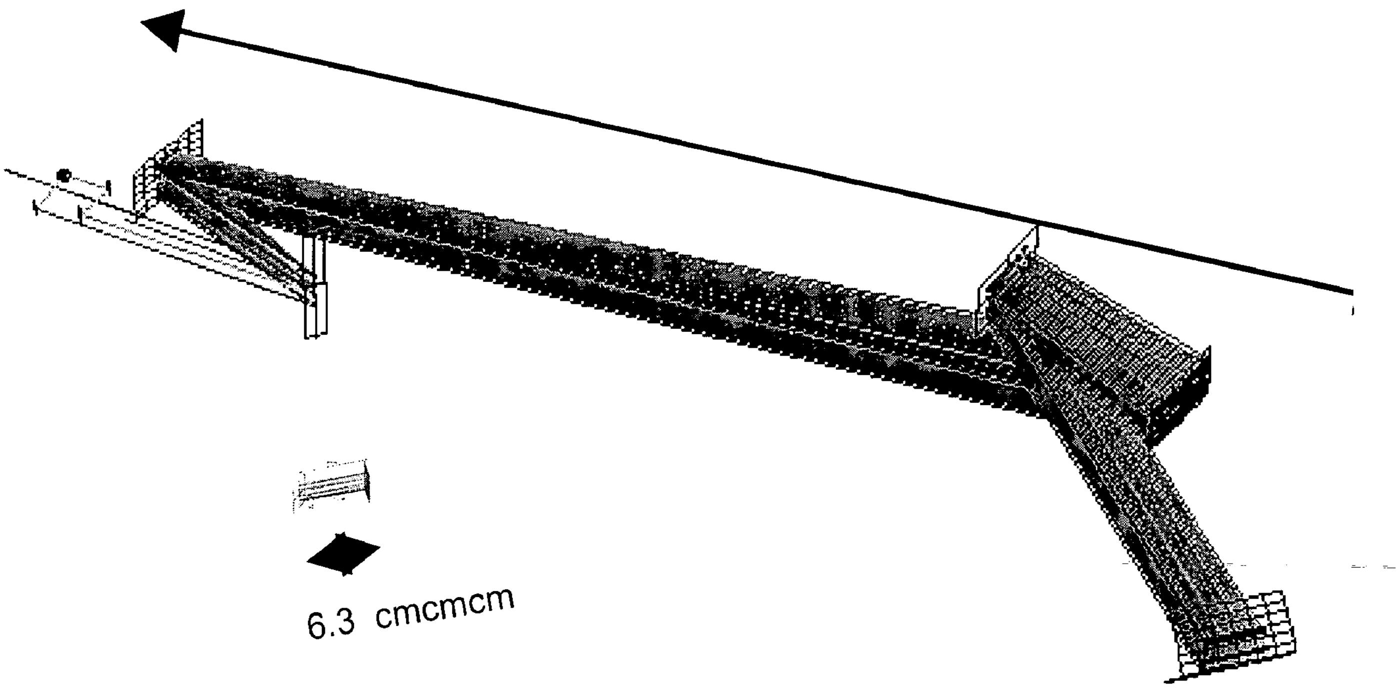
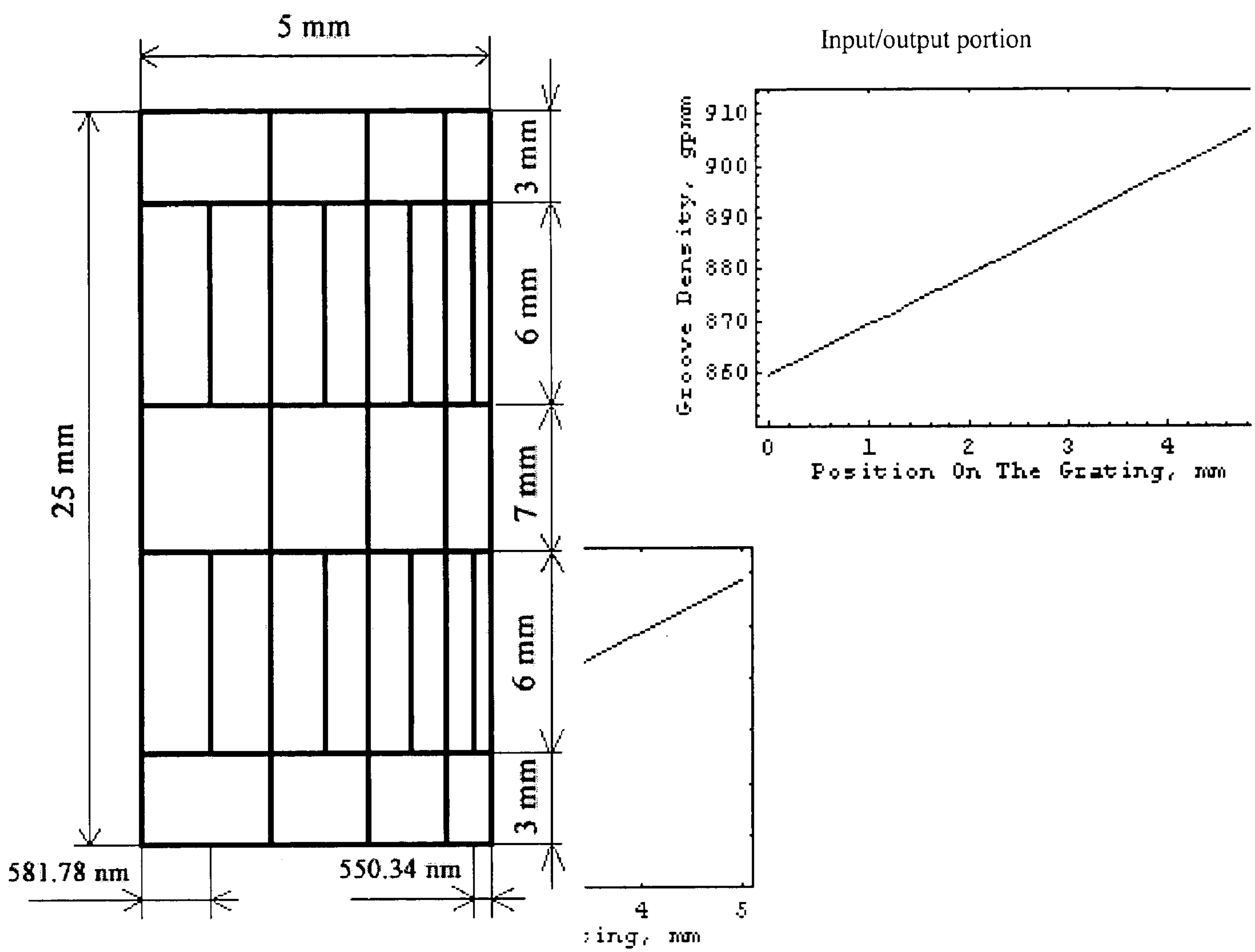


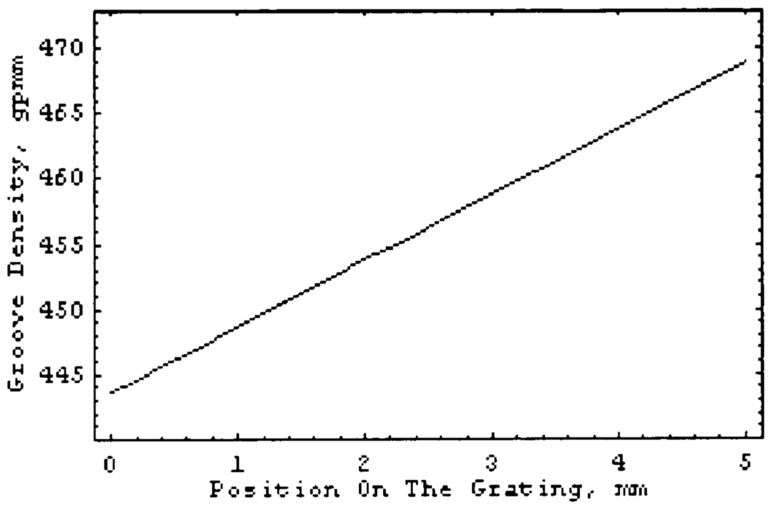
FIGURE: 9



5 mm
25 mm
3 mm
6 mm
7 mm
6 mm
3 mm
581.78 nm
550.34 nm
Input/output portion
Groove Density, gpmm
910
900
890
880
870
860
0
1
2
3
4
Position On The Grating, mm
4
5

Figure 10

Input/Output Portions



Other Portions

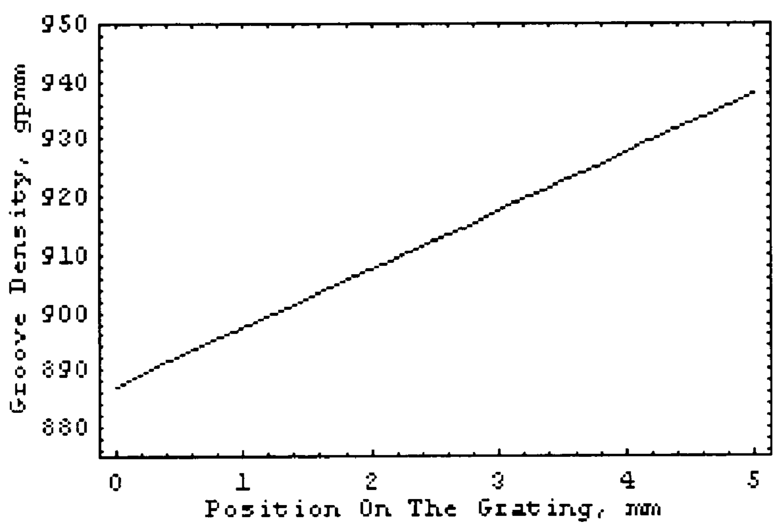
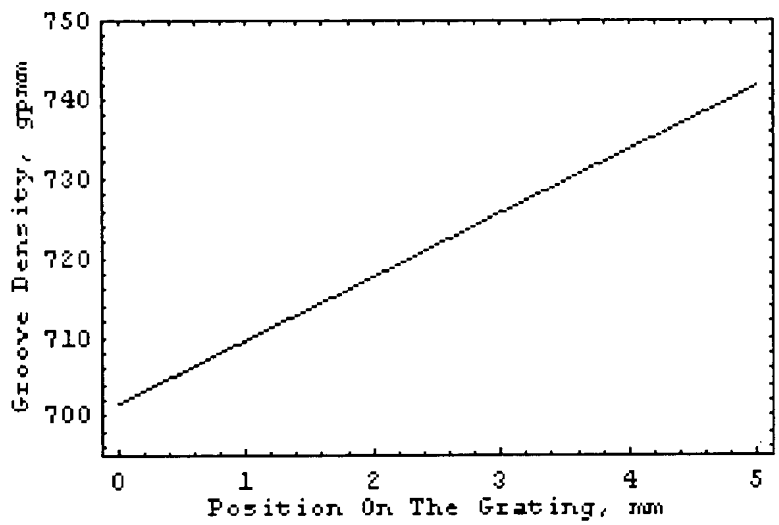


Figure 11

Input/Output Portions



Other Portions